Linkages Between North Atlantic Right Whales and their Habitat

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Acknowledgements

- Collaborators

Cornell	Bruce Monger, Charles Greene
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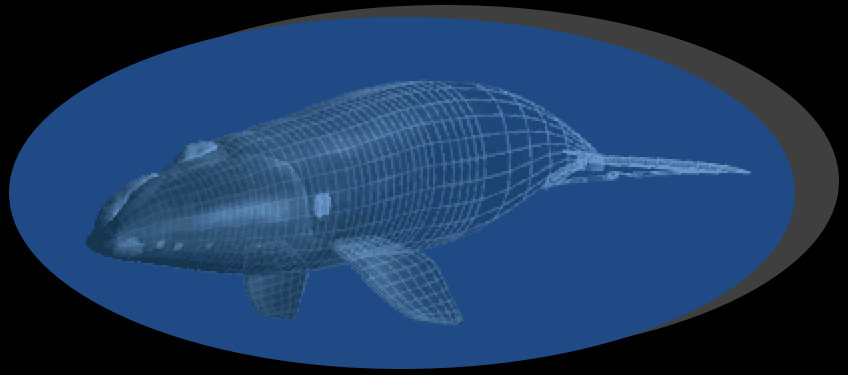
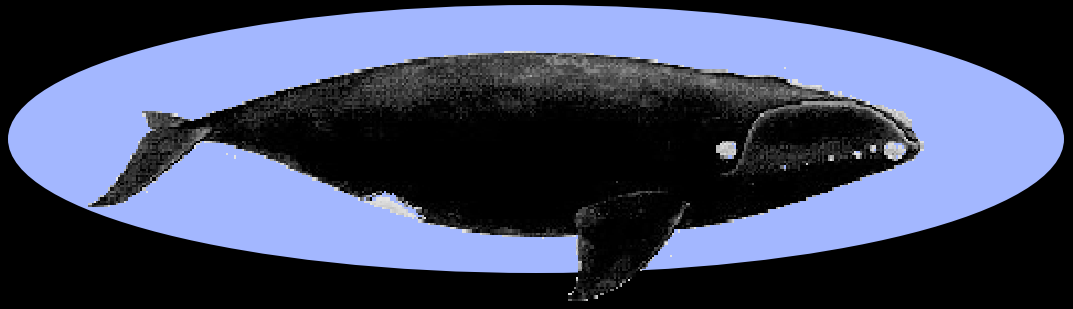
  - NOAA Coastal Services Center
  - NOAA Right Whale Grants Program
  - NASA Decision Support

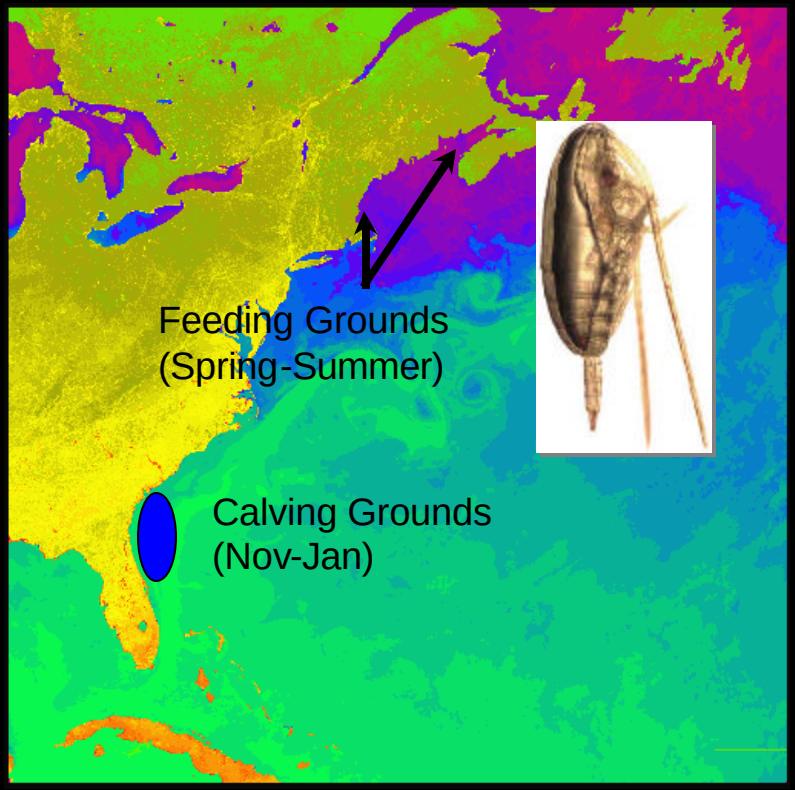
Outline

- Right whales & the Gulf of Maine ecosystem
  - Copepods and calves
  - Climate, salinity, and herring
- Cetacean informatics
  - Synthesizing information with models
  - Linking satellite data to whale distributions



Right Whales 101

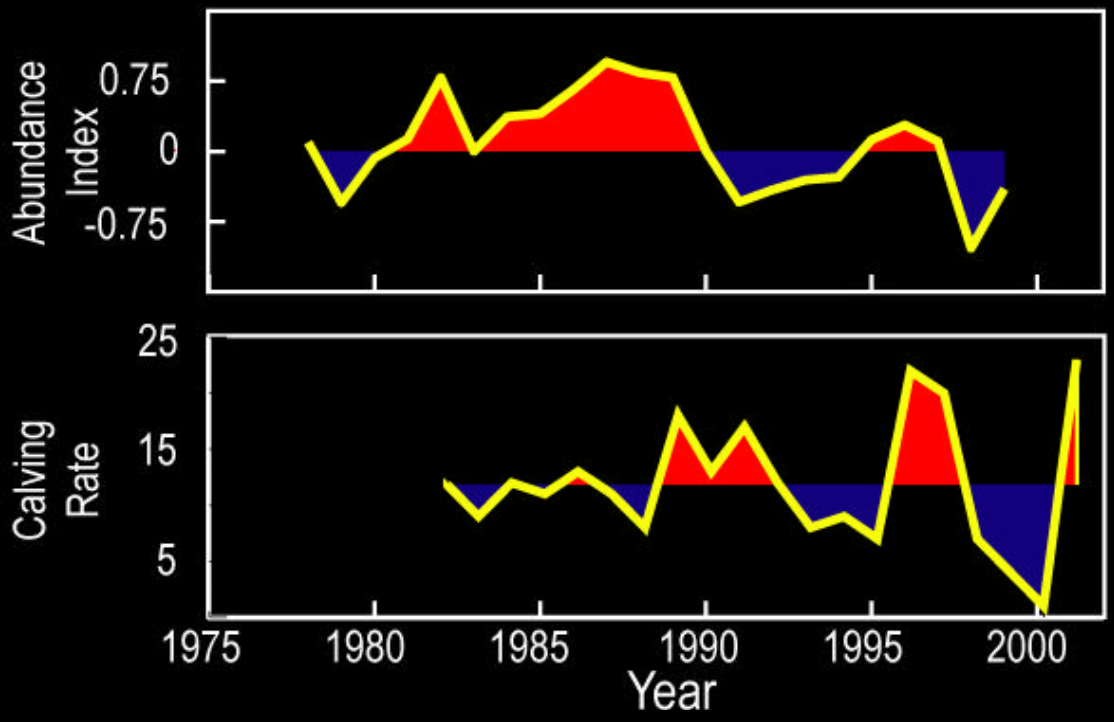




- Why the long face?
  - Lonely (350)
  - Getting lonelier—extinct in 200 yrs?
- All known feeding grounds in Gulf of Maine/Scotian Shelf
- Main prey: *Calanus finmarchicus*

Gulf of Maine Time Series

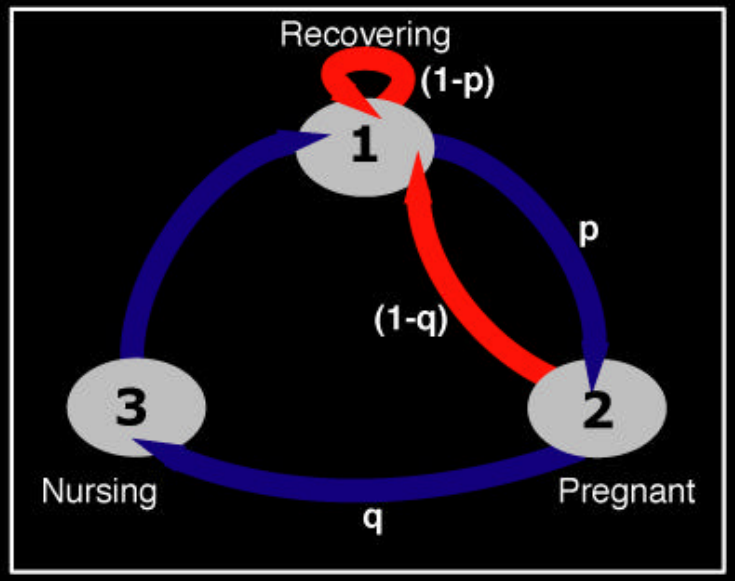
- Hypothesis: right whale birth rates are related to *Calanus* abundance



- No significant *linear* correlation with *Calanus*

Right Whale Reproduction

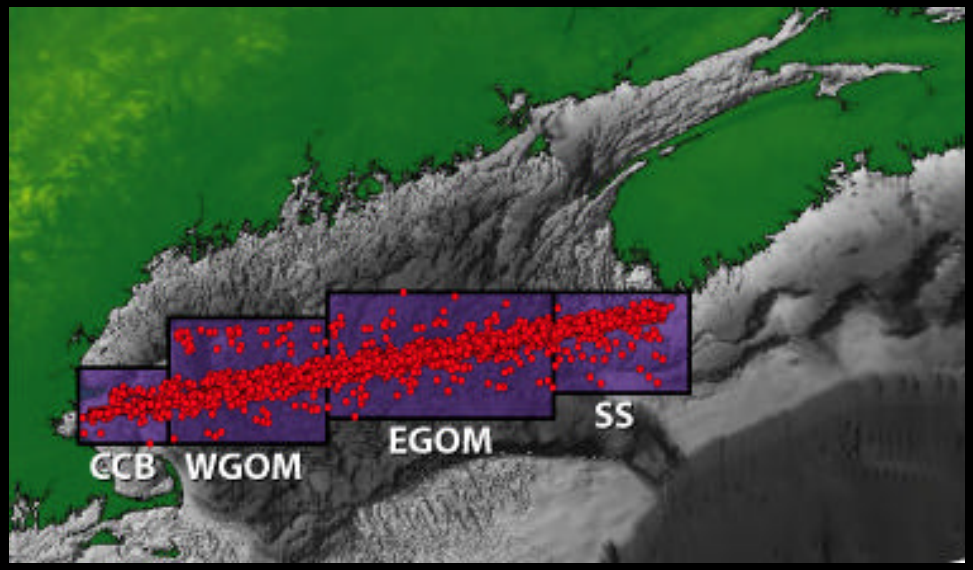
- But, whales are nonlinear…



–3 year reproductive cycle

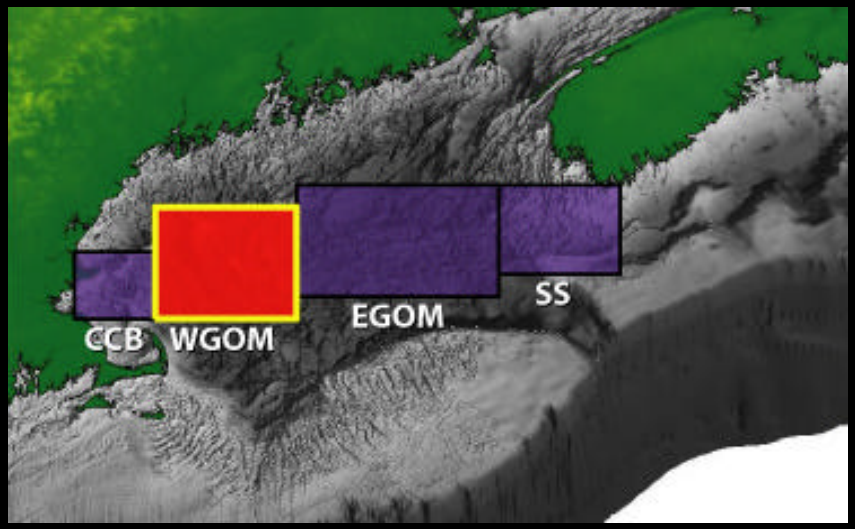
–Find probability functions giving best agreement with observations

Regional Relationships



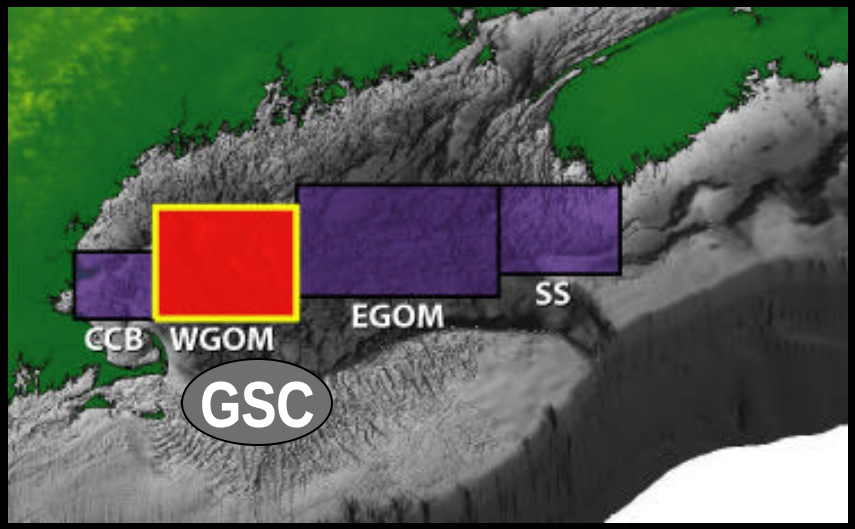
- Divided Gulf of Maine into 4 regions
- Tested seven *Calanus* series from each region:
  - 6 bi-monthly periods
  - yearly average

Results



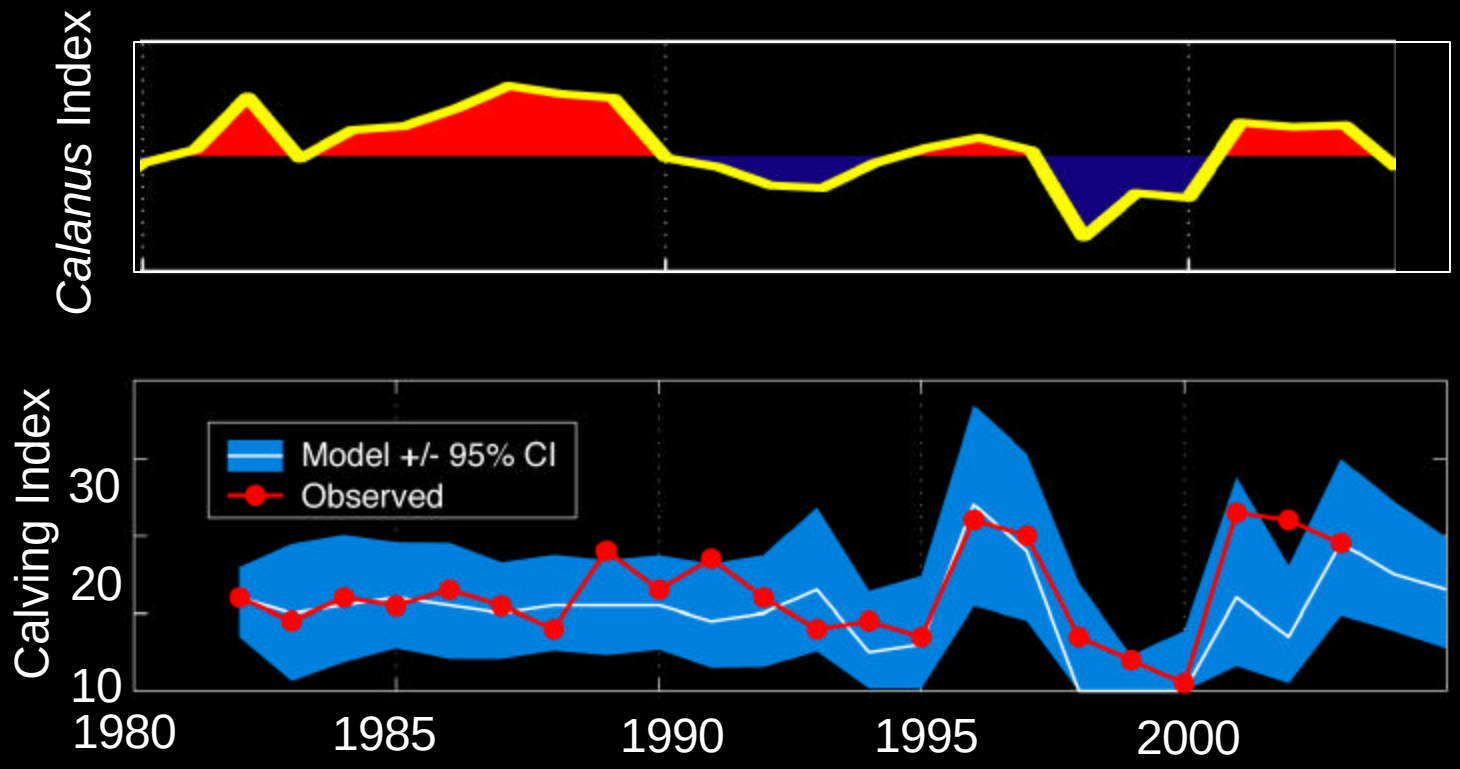
- *Calanus* in western Gulf of Maine is a good predictor of right whale births
  - Yearly average is best ($p<0.01$)
  - May-June and July-August periods are good ($p<0.05$)

Results



- *Calanus* in western Gulf of Maine is a good predictor of right whale births
  - Yearly average is best ($p<0.01$)
  - May-June and July-August periods are good ($p<0.05$)
- Right whales feed in Great South Channel, especially in March-May

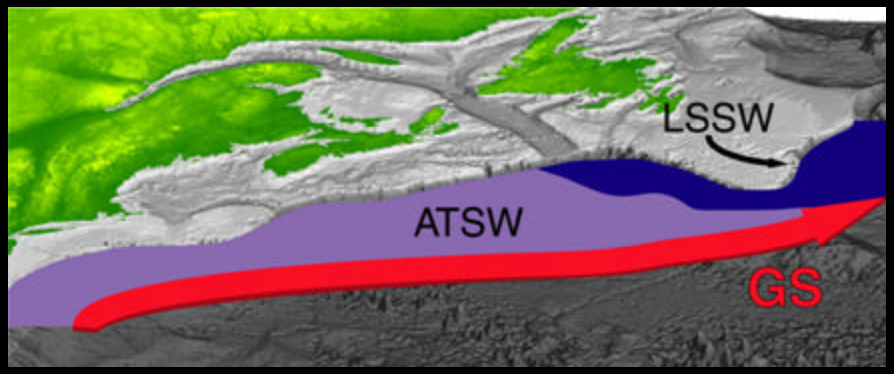
Results



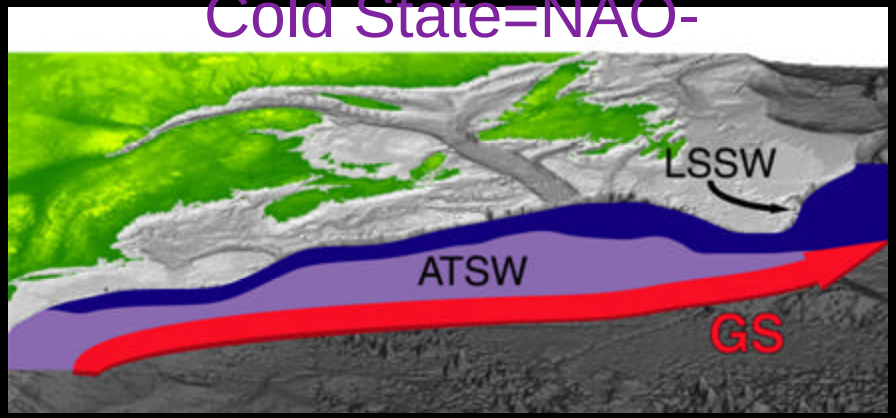
- Low birth rate in 1990s related to *Calanus*
- Model also implies that feeding before pregnancy most important

Climate Impacts

Warm State=NAO+

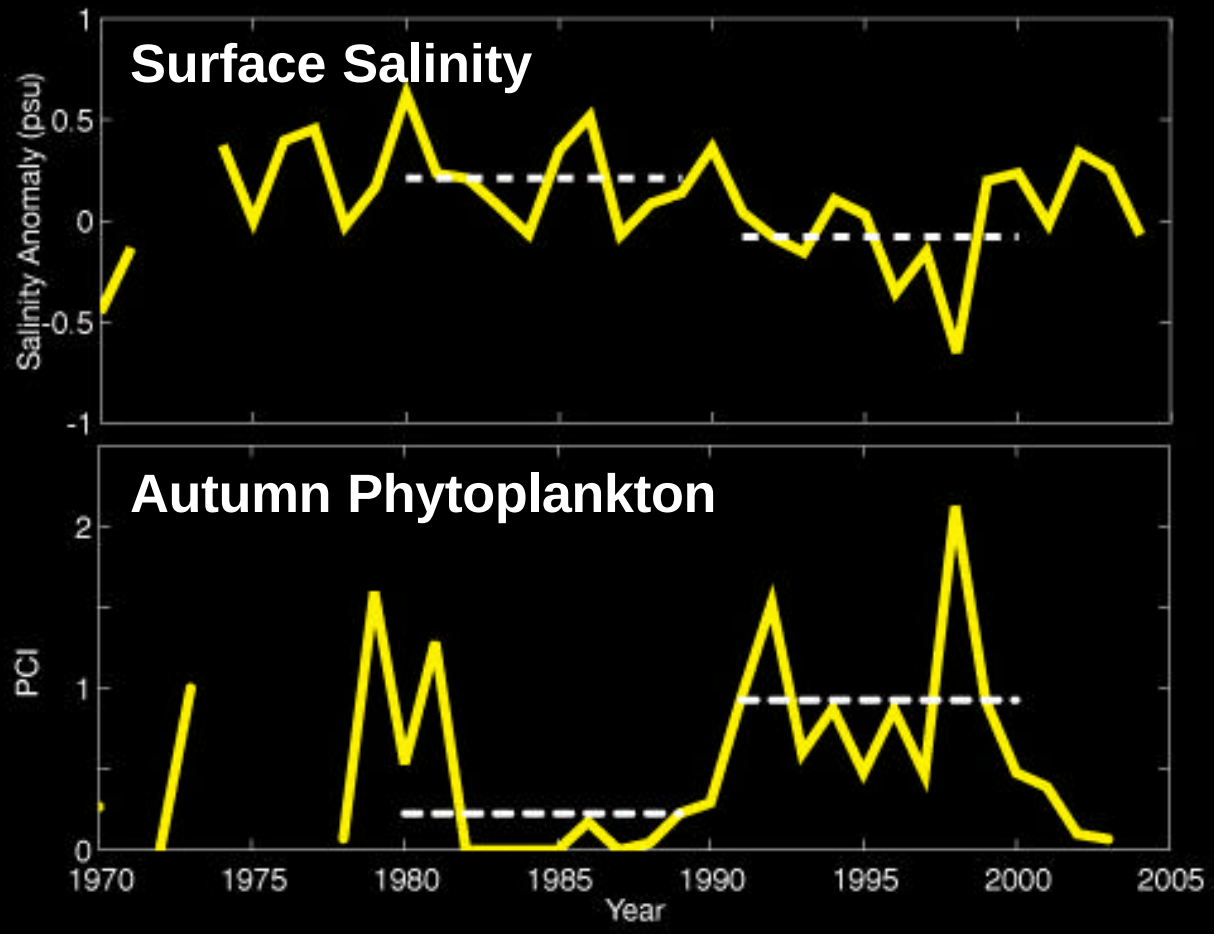


Cold State=NAO-



- Changes in N. Atlantic impact the Gulf of Maine
- Strongest changes come from Labrador Sea

Possible Mechanism



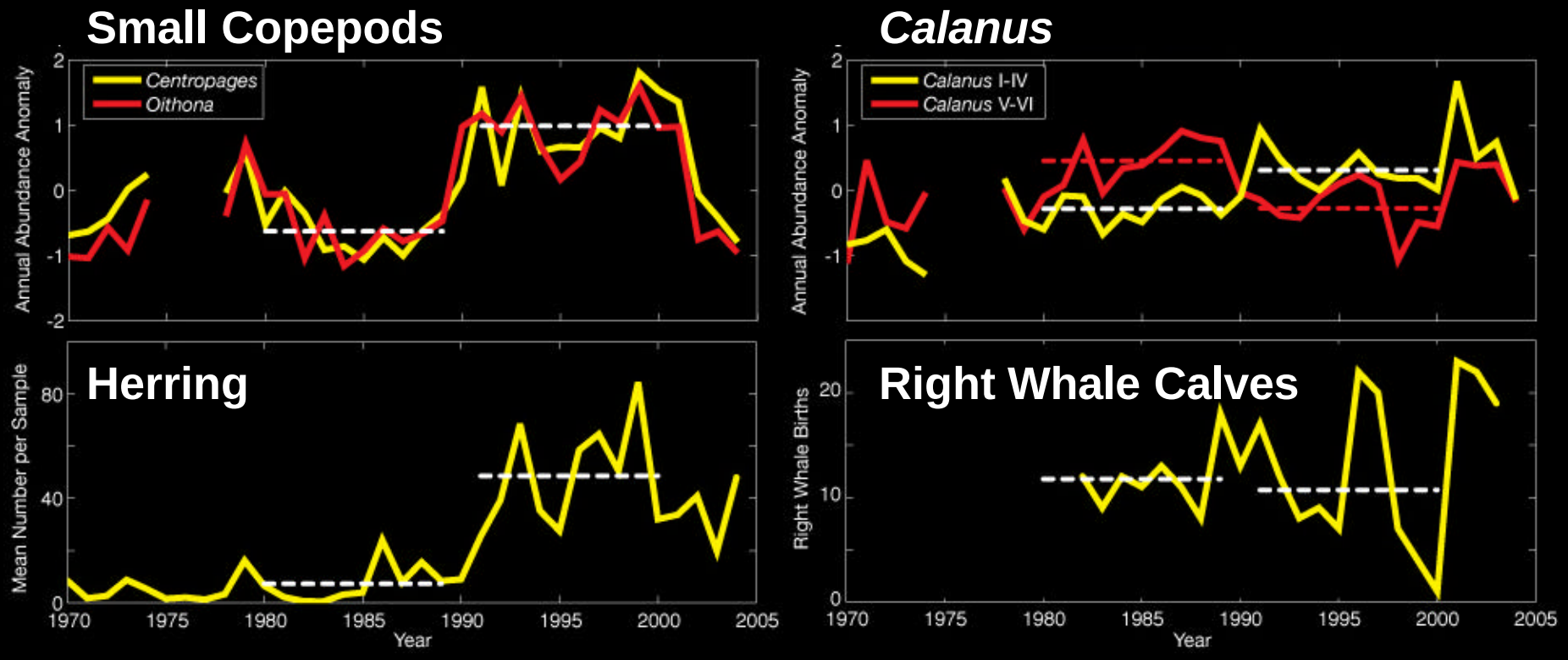
Reduced surface salinity

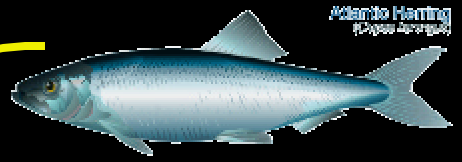
Bigger fall bloom

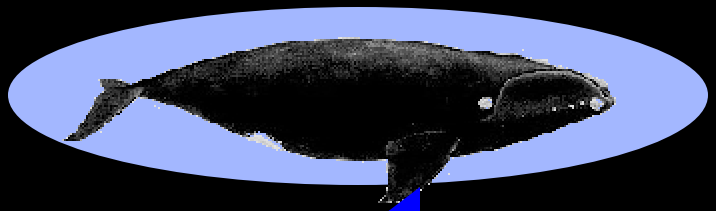
Increased copepod reproduction (e.g. Durbin et al. 2003*)

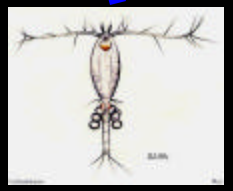
*MEPS 254:81-100

Impact of Shift



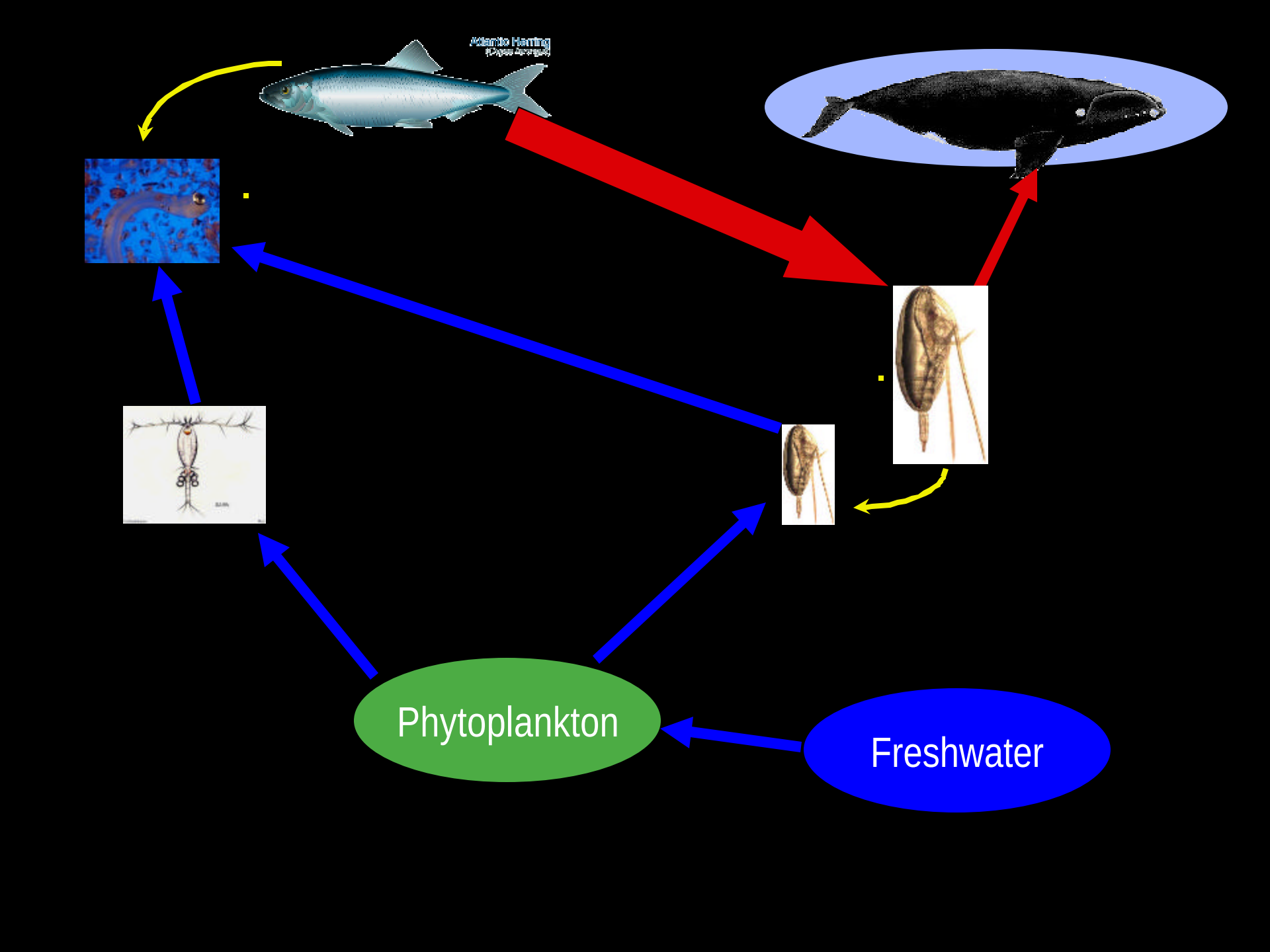






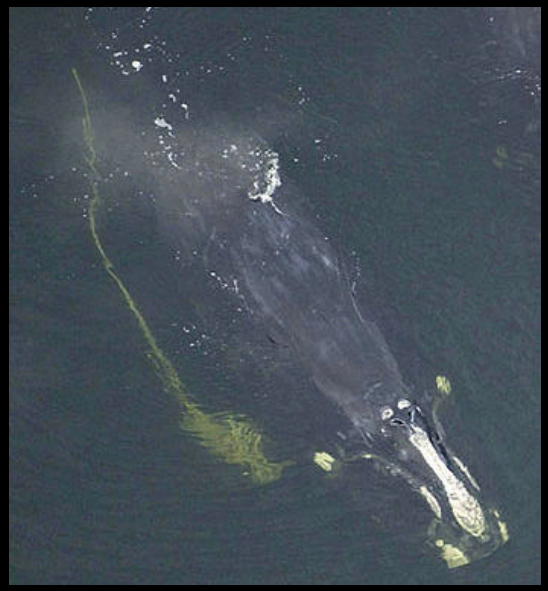
Phytoplankton

Freshwater


Atlantic Herring
Phytoplankton
Freshwater

Right Whale, Wrong Time?

- Not much we can do about birth rates
- More options for mortality
  - Ship strikes
  - Fishing gear



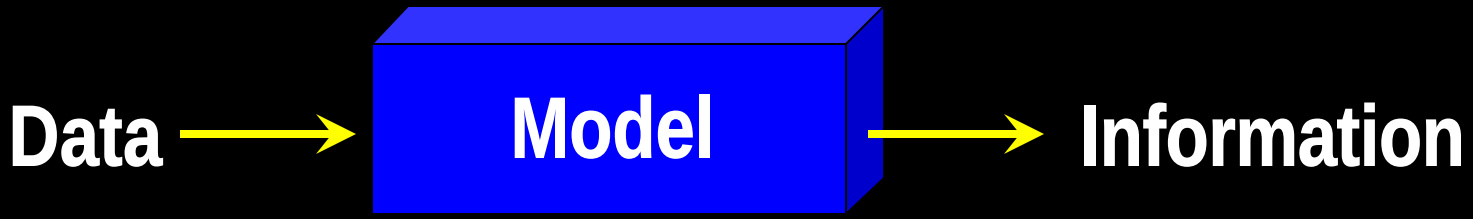
Saving the Whales

- Predicting births is interesting, but of little management value
  - Need to know where/when whales are
- But, suggests that food is very important, especially for females
  - Implication: identifying feeding areas should be a good way to locate whales
  - Focus on modeling whale food

Cetacean Informatics

- We collect a lot of data from the Gulf of Maine
  - SST, chlorophyll from satellites
  - Hydrography and meteorology from buoys
  - Zooplankton from surveys
- Information=when/where right whales are likely
- Need knowledge to produce information from available data

Cetacean Informatics



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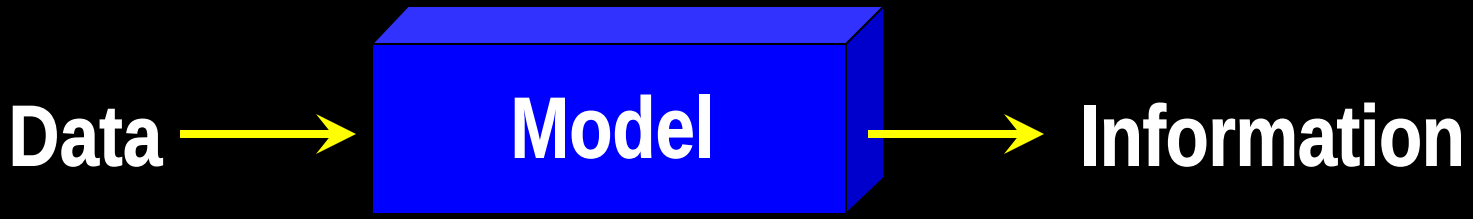

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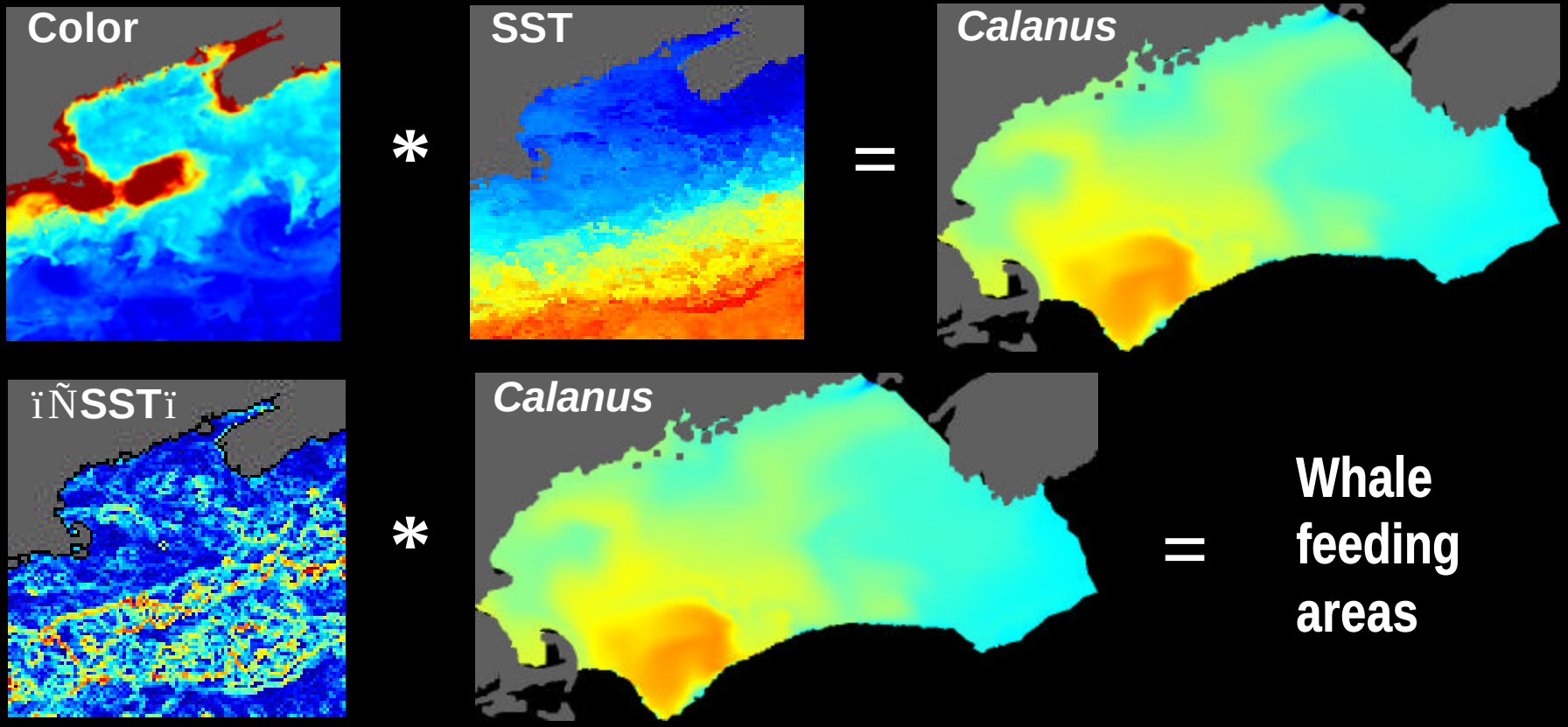
Whale Food

- Main prey--*Calanus finmarchicus*
  - Abundant, big, fat
- Idea
  - *Calanus* development rates are linked to temperature
  - *Calanus* egg production is linked to food (chlorophyll)
  - Satellite data should be good indicator of *Calanus* dynamics

RWPS 1.0

- Ran system for 1998-2004, Jan-June
- Data available at www.geo.cornell.edu/whales



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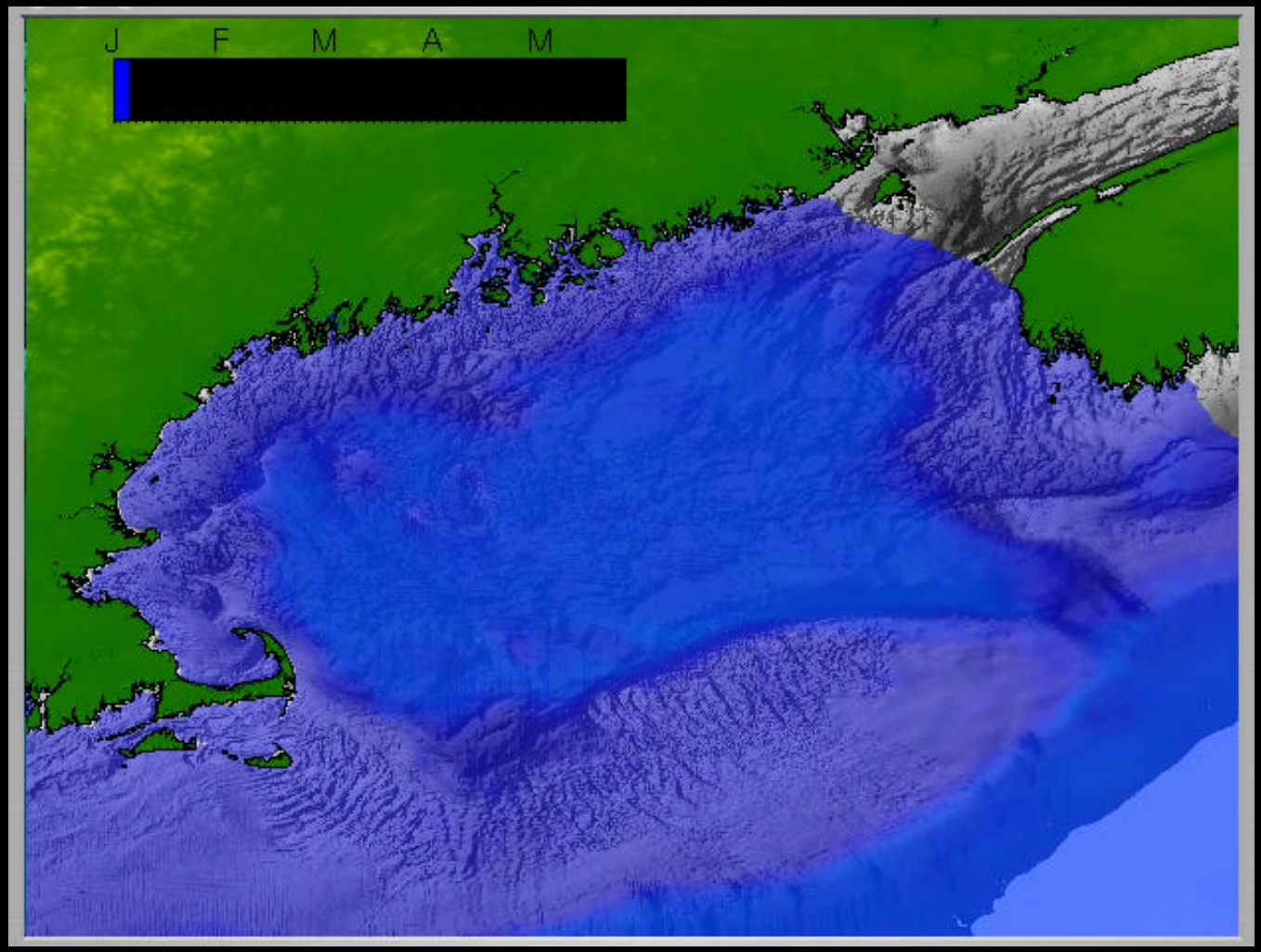

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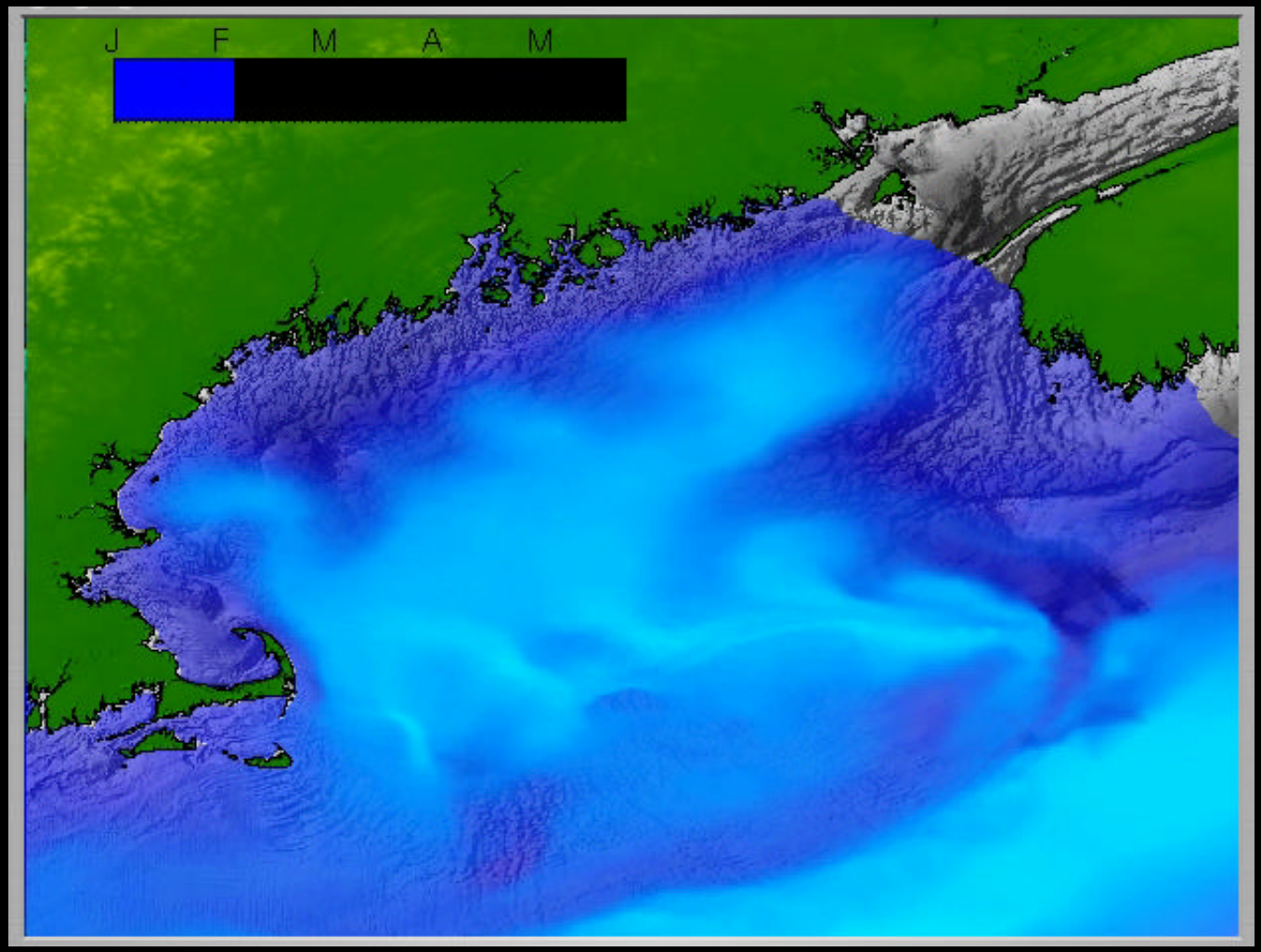

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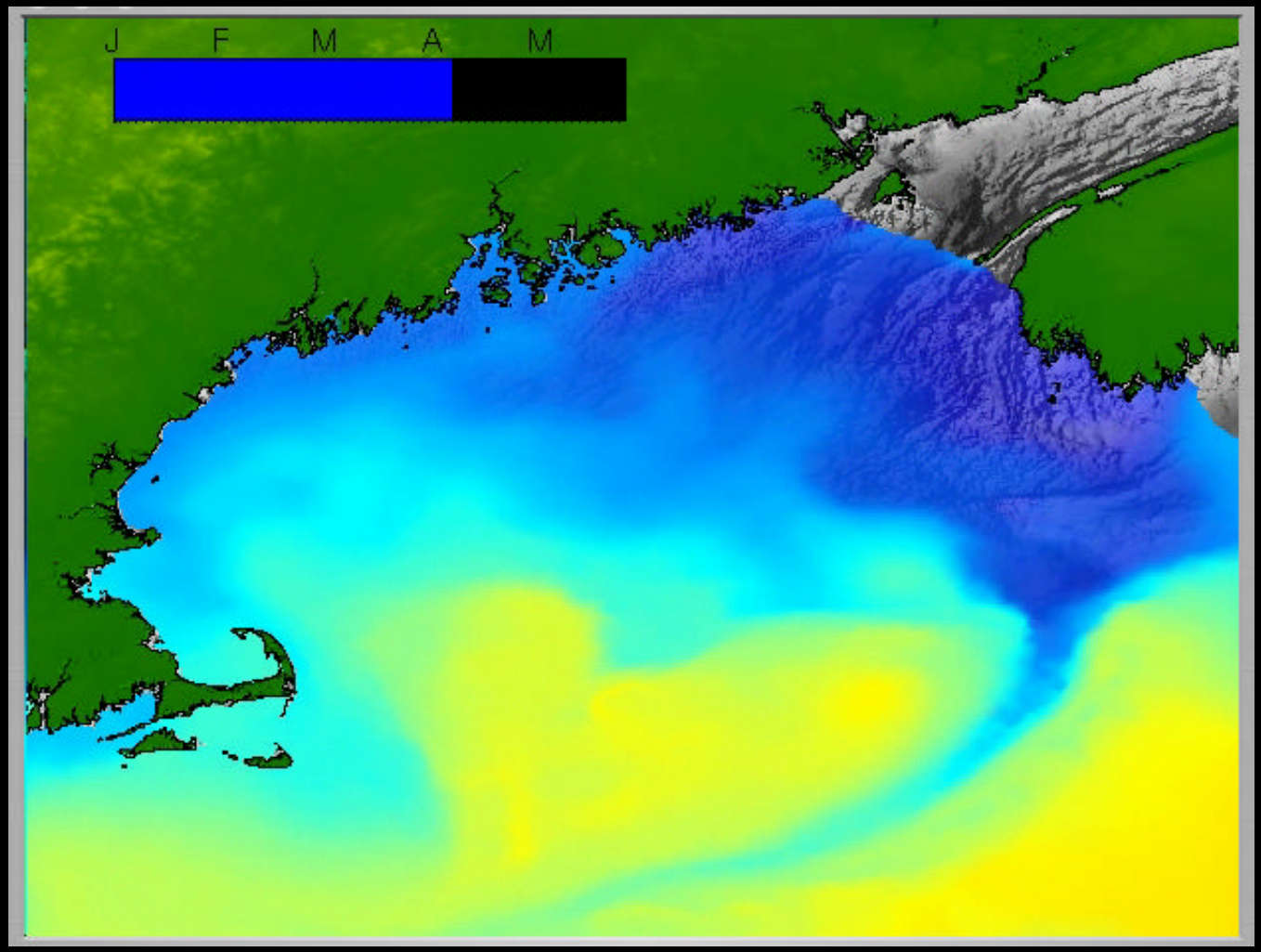

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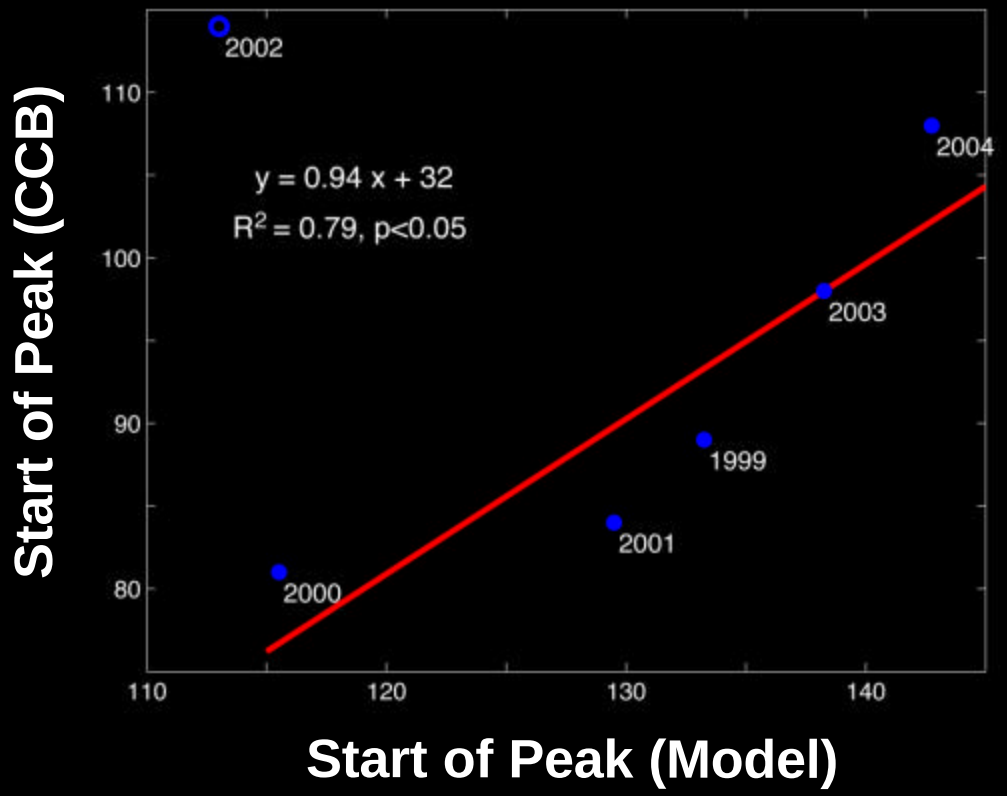
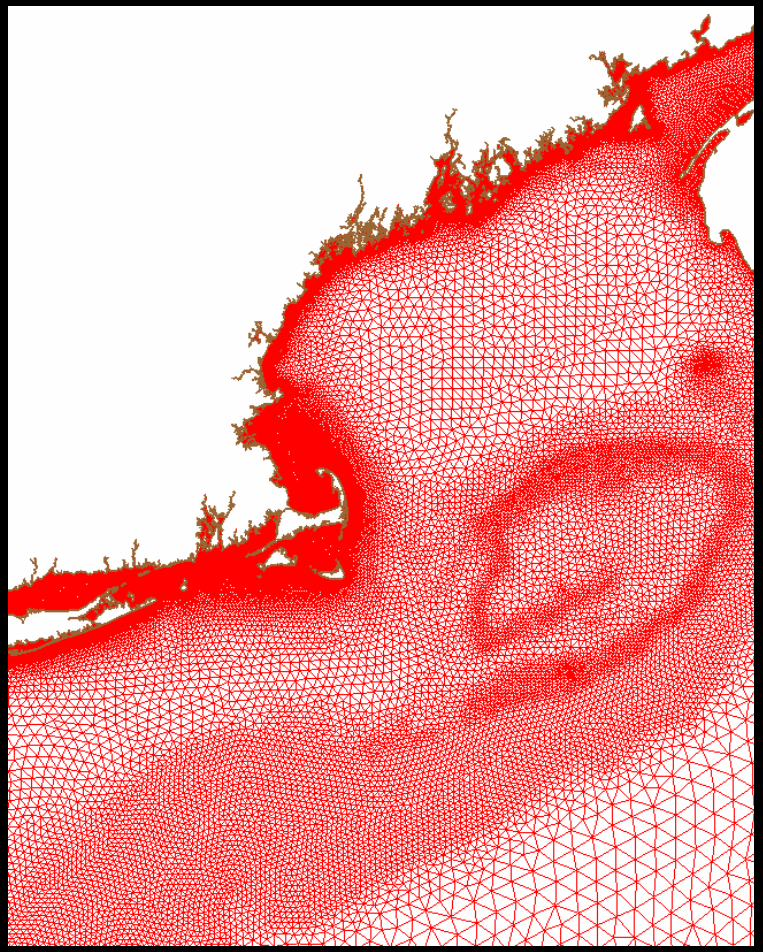
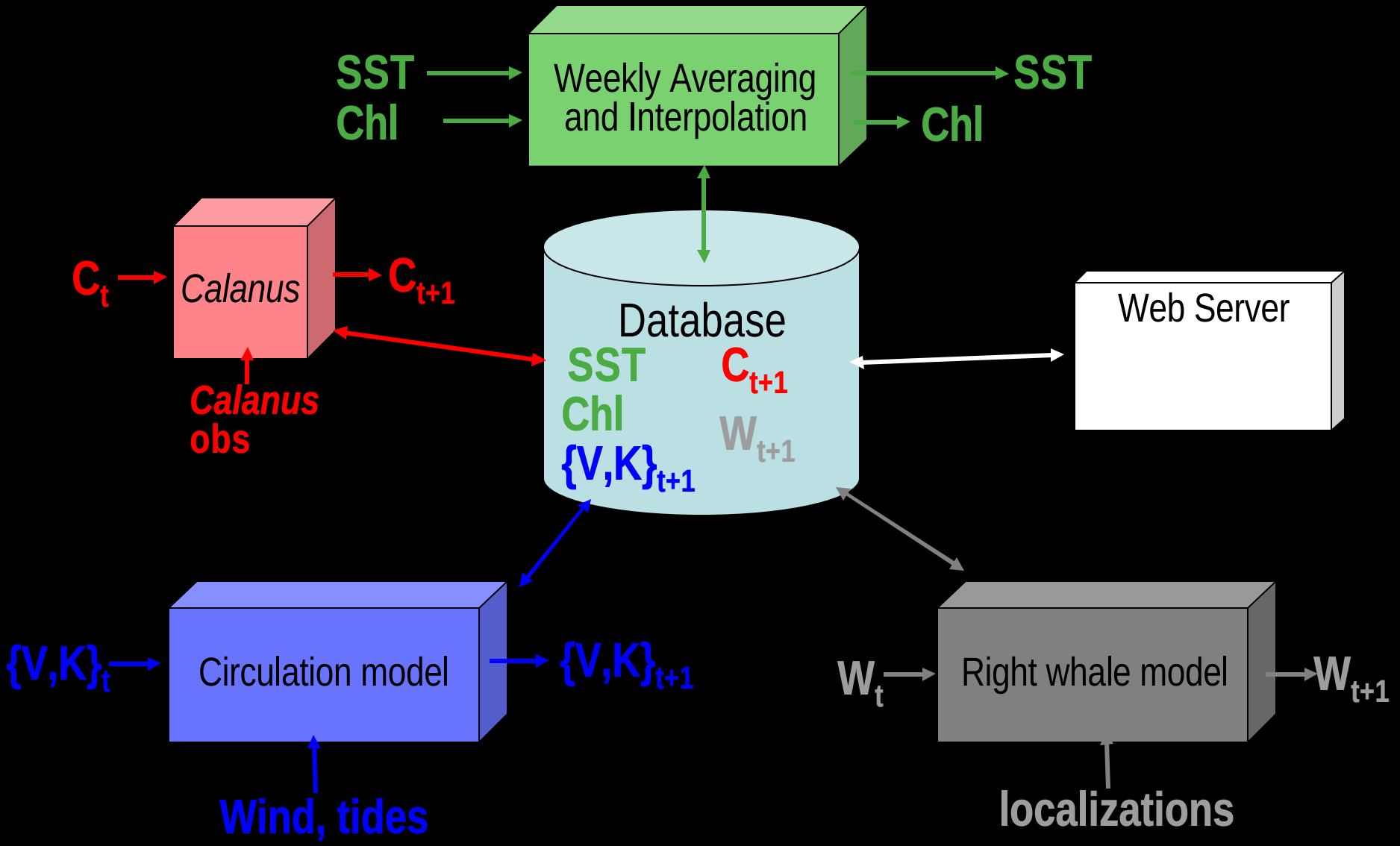

Start of Peak (CCB)
Start of Peak (Model)
y = 0.94 x + 32
R2 = 0.79, p<0.05
2002
2004
2003
1999
2001
2000
110
100
90
80
110
120
130
140

Operational Models



- Operational Oceanography
  - Real-time estimates of ocean state
  - Assimilate observations into model
  - These are a tremendous resource that biologists should exploit
- Can apply the same concepts to biology
  - Synthesize multiple observations
  - Extend observations in space and time
  - Will apply to CCB zooplankton distributions

RWPS 2.0


SST
Chl
Weekly Averaging and Interpolation
SST
Chl
C_t
Calanus
C_{t+1}
Calanus obs
Database
SST
Chl
C_{t+1}
W_{t+1}
$\{V,K\}_{t+1}$
Web Server
$\{V,K\}_t$
Circulation model
$\{V,K\}_{t+1}$
Wind, tides
W_t
Right whale model
W_{t+1}
localizations

Summary

- Two themes
  - Need to understand how species fit into ecosystem
    - Actions for one species could affect another
    - Ex: Herring, right whales (tuna, humpbacks, cod…)
  - Models, models, models
    - Formalizations of how we think processes are connected
      - Ex: connect satellite data to *Calanus* and right whales
    - Operational circulation models provide accurate description of ocean's 3D state
      - Link habitat to actual processes not proxies
      - Apply the same ideas to biology